THE COMPLEX OF IMAGE PROCESSING ALGORITHMS FOR GRANULOMETRY OF CHARGING MATERIALS

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Abstract. The paper is dedicated to the application of image enhancement algorithms for automated granulometry of charging materials that are used in an electric arc furnace. The image processing is performed by means of the algorithms of the OpenCV open source computer vision library. With the purpose of improvement of a source color image of charging materials, preliminary and morphological image processing are carried out. In the course of the preliminary image processing, the image is undergone to adjustment of the contrast and brightness, at the same time the image histogram, which is the indicator of the image contrast, is calculated. The image is also undergone to bilateral filtering in order to reduce its noisiness. Morphological image processing involves carrying out of dilation and erosion operations on the image. The result of the image enhancement operations is the image that is suitable for image segmentation and recognition.

Keywords: image processing, image enhancement, preliminary image processing, image histogram, morphological image processing, granulometry.

Introduction

At present, processing and analysis of digital images represent an effective tool suitable for solving many practical problems. Image processing is widely used in medicine, industry, defense sector and other fields [1]. Despite the fact that this region is a relatively young science, image processing has been broadly developed and presents a promising trend for its further development.

Research on using automated processing algorithms to determine quality of metal products have been recently carried out [2 – 3]. The authors have set the goal of creating an automated system for granulometry of charging materials used as a part of the burden for an electric arc furnace [4-5]. The granulometry will be performed by means of processing and analysis of a color RGB image of the charging materials (fig. 1). The processing and analysis are implemented by means of the algorithms of the OpenCV open source computer vision library and follow the path, the flowchart of which is illustrated in fig. 2 [6].

Fig. 1. Fragments of images for granulometry of charging materials:
a – areas of limestone granules; b – areas of lime granules; c – areas of fluor-spar granules

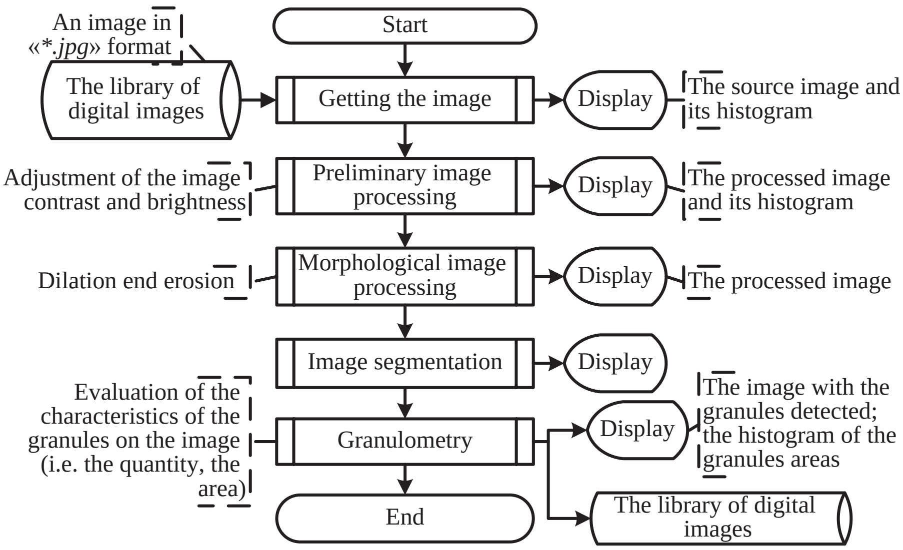


Fig. 2. Functional diagram of the image processing system

A source image, which is the input for the program, may have some features that argue insufficient quality of the image and require image processing to enhance it. The possible features are image noisiness, low contrast, high brightness and vice versa low brightness, low sharpness, presence of some foreign objects against the image background. So, the first stages of the image processing are related with the image enhancement. The final stage is granulometry of the charging materials. The paper discusses the complex of preliminary and morphological image processing algorithms aimed at enhancement of a source image of charging materials.

Image enhancement algorithms

Digital images are characterized by discrete presentation of data. Each component (pixel) is represented by its *intensity function*, or *gray level*, $f(x, y)$, where x and y are space coordinates in the plane [1]. In the case in question processing is performed on an RGB image which is a three-channel one and consists of *red*, *green* and *blue* components.

Preliminary image processing

Adjustment of the contrast and brightness of an image. The operations on an image are one of the simplest these and intended for processing of an image having low contrast, high or low brightness. The defects may have appeared, for instance, because of poor illumination of the shooting place. Adjustment of the contrast and brightness of an image are formulated as follows [7]:

$$g(x) = \alpha \cdot f(x) + \beta, \tag{1}$$

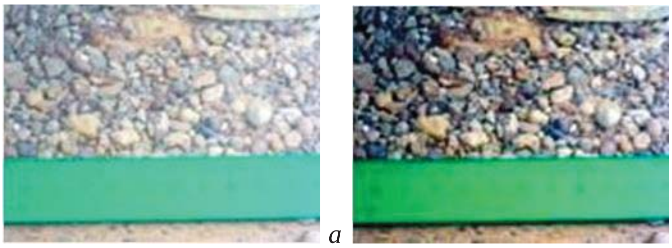
where $f(x)$ represents an input image and $g(x)$ represents the output image; $\alpha > 0$ adjusts the image contrast; β adjusts the image brightness.

The result of the operations depends only on an input pixel and doesn't depend on its neighbour pixels. Since the data have discrete presentation and the image pixels are located in the space domain in the plane, the expression (1) may be represented as follows [7]:

$$g(i, j) = \alpha \cdot f(i, j) + \beta, \tag{1}$$

i and j denote, that the pixel is located in the i-*th* row and j-*th* column of the image matrix.

The result of adjustment of the source image contrast and brightness with values α=*1,7* и β=*-178* is shown in fig. 3.



a *b*

Fig. 3. The image of charging materials to be processed:
a – its unmodified state; b – the image after the adjustment of the contrast and brightness

As fig. 3 shows, the source image has gained more qualitative form after the adjustment of its contrast and brightness. The image contrast has increased and the contours of the objects have become more distinguishable.

Image histogram calculation. The histogram of a digital image, having intensity levels in the range of [0, L – 1], is the discrete function $h(r_k) = n_k$, where r_k corresponds to the k-*th* intensity level and n_k equals the number of pixels having such an intensity level [1]. The image histogram is inherently the indicator of the image contrast and thus the indicator of the image quality. A histogram is calculated on the basis of the data on the image pixels intensity. It is advisable to calculate an image histogram simultaneously with adjustment of the contrast and brightness of the image because the image histogram provides objective information about the image contrast.

Since the operations are performed on an *RGB* image, the image histogram is calculated separately for each channel of the image (red, green, blue). The histogram is calculated using the following algorithm [8]:

1. Splitting the image in its *R*, *G*, *B* planes.
2. Setting 256 equal histogram bins, since the intensity levels cover the range of [0, 255].
3. Calculating the histogram of each of the channels.
4. Normalizing the histograms to level its values over the histogram altitude range.
5. Displaying the histograms of the R, G, B planes on the screen.

Images having low contrast are characterized by non-uniform distribution of its intensity values over the available intensity range and distribution of the values in some narrow range. Fig. 4 shows the histograms of the R, G, B planes of the source image (fig. 3 a) and the image that has been undergone to adjustment of the contrast and brightness (fig. 3 b).

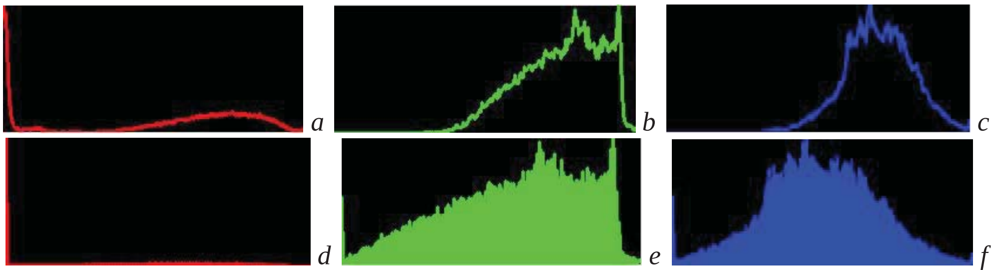


Fig. 4. The image histograms: a, b, c – the histograms of the R, G, B planes of the source image; d, e, f – the histograms of the R, G, B planes of the processed image

Fig. 4 a, fig. 4 b, fig. 4 c show non-uniform distribution of the intensity values for all of the channels of the source image. For the R-plane the peak of the distribution corresponds to the region of minimal intensity values, the G-plane and the B-plane are also characterized by non-uniform distribution of the intensity values with the largest values cluster on the right side of the histogram, i.e. in the region of average and maximum intensity values.

After adjustment of the contrast and brightness of the source image, the distribution of the intensity values on the histograms of the processed image (fig. 4 d, fig. 4 e, fig. 4 f) has become more uniform for all of the planes, but nevertheless the peak on the left side of the R-plane histogram has remained. Thus an image histogram represents a tool, that indicates the level of the image contrast when adjusting the image contrast and brightness and supplements the user’s visual assessment of the image quality.

Noise suppression using bilateral filtering. Source images often have noisiness that may have appeared, for instance, during operation of the camera or because of low illumination of the shooting place. To accomplish image segmentation and recognition correctly, it is necessary to reduce or fully eliminate the noisiness, and this may be effectively done using image filtering.

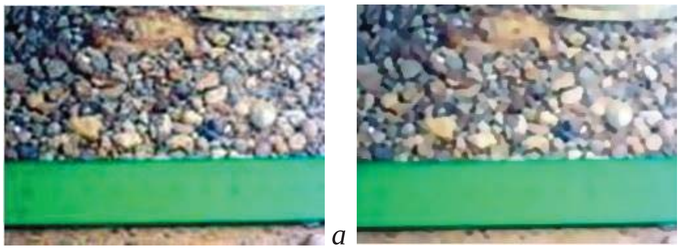
Following the broad sense of the term “*filtering*”, the value of a pixel of a filtered image is a function of the pixels values that are located in some neighborhood of the pixel [9]. The algorithm of *bilateral filtering* for noise suppression combines image filtering both in the aspect of space location of the image pixels and in the aspect of their intensity values, thus enforcing both geometric and photometric locality [9 – 10]:

$$g(i,j)=\frac{\sum_{k,l} f(k,l)\cdot w(i,j,k,l)}{\sum_{k,l} w(i,j,k,l)}. \quad (3)$$

The weighting coefficient $w(i, j, k, l)$ is the combination of domain and range data of the pixels.

Bilateral filtering smoothes an image and at the same time enables to keep the contours of the objects on the image. The latter is an advantage of such a kind of filtering because keeping of object contours is of great importance to perform image segmentation and recognition correctly.

The image of charging materials, which is the result of adjustment of the contrast and brightness, has noisiness as well as its source version does (fig. 3). Therefore to reduce the image noisiness it has been undergone to bilateral filtering, the result of which is shown in fig. 5. Thus such a kind of filtering has enabled to reduce the noisiness of the image and keep the contours of the objects on the image.



a *b*

Fig. 5. Bilateral filtering of the image of charging materials: a – the source image; b – the filtered image

Morphological image processing

Morphological image processing, like preliminary image processing, enables to enhance image quality and make the image more applicable for its further processing and segmentation. The methods of morphological processing are widely used, for example, for suppression of image noise, isolation or merger of separate elements on the image, bonding of breakthroughs, *etc* [11 – 13].

The basic morphological operations are *dilation* and *erosion*. The operations consist in *convoluting* an image *A* with some *structuring element B*, similarly to filtering. Dilation and erosion are formulated in general as follows (formulae (4) and (5), respectively) [12]:

$$dilate(x,y) = \max_{(x',y') \in kernel} src(x+x', y+y'); \quad (4)$$

$$erode(x,y) = \min_{(x',y') \in kernel} src(x+x', y+y'), \quad (5)$$

where *(x,y)* denote space coordinates of some point of an image.

Dilation and erosion on an image stand for morphological *enlargement* and *narrowing*, respectively, of regions. More often the structuring elements of the morphological operations have the shape of a *rectangle*, a *cross* or an *ellipse* having 3×3 size and the *anchor point* at the center.

With the purpose of enlargement of the bright regions, dilation with 3×3 ellipse has been applied to the image of charging materials after its bilateral filtering (fig. 6). The dilation has been carried out using the algorithm from [11]. The operation has resulted in enlargement of the bright regions, corresponding to the areas of granules, and has enabled to form more unicoloured regions of the objects, what, in turn, should affect correct image segmentation. Fig. 6 also shows the source image of the charging materials to compare the results of its enhancement.

a *b* *c*

Fig. 6. Dilation of the image: a – the source image; b – the result of bilateral filtering of the image; c – the result of dilation of the image

Conclusions

The paper has discussed the complex of image processing algorithms, aimed at enhancement of a source RGB image of charging materials in the course of automated granulometry of the materials. The enhancement algorithms include preliminary and morphological image processing. In the course of the preliminary image processing, adjustment of the contrast and brightness of the source image has been performed to enhance its contrast. The adjustment at the same time involved calculating of the image histogram for each channel of the image (R, G, B), being the indicator of the image contrast. As the result, the image has become more contrast and the contours of the objects have become more distinguishable. Then with the purpose of reducing the noise, the image has been processed using the algorithm of bilateral filtering that enables to accomplish image filtering and keep the objects contours. The result of the bilateral filtering has shown decreasing of the noisiness, at the same time the contours haven't been blurred. The final stage of the image enhancement involved morphological dilation, which has resulted in some enlargement of the bright regions of the areas of granules and has enabled to make the regions more unicoloured. The latter should in some degree simplify the image segmentation.

Within the future work it is planned to implement algorithms of image segmentation and recognition, which will result in granulometry of the charging materials represented on the image. The input for the stages will be the image, that has been obtained as the result of the enhancement operations described in the paper.

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